Energy-Saving and Process Technologies Development at ORNL

Michael MacDonald
Engineering Science and Technology Division
DOE Oak Ridge National Laboratory

for the

Industrial Process and Energy Optimization Workshop

Gettysburg, PA

February 26, 2004

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
26 FEB 2004	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Energy-Saving and Process Technologies Development at ORNL	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Engineering Science and Technology Division DOE Oak Ridge National Laboratory**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001865, Industrial Process and Energy Optimization. Proceedings of the Industry Workshop Held in Gettysburg, PA, 25-27 February 2004., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**42**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Oak Ridge National Laboratory today

- **$1 billion budget**
- **DOE's largest multiprogram science laboratory**
- **Nation's largest energy R&D laboratory**
- **Building the $1.4 billion Spallation Neutron Source**
- **Building the $0.8 billion Center for Nanophase Materials Sciences**
- **3700 employees**
- **3000 research guests annually**
- **~20 user facilities**
- **$300 million modernization program in progress**

We support DOE's energy mission

Generation

- **Distributed energy resources**
- **Hydrogen**
- **Fusion**
- **Nuclear**

Distribution

- **High-temperature superconductors**
- **Transmission technology**

Consumption

- **Buildings**
- **Transportation**
- **Industry**

ORNL's science base

National/Homeland Security

- **SensorNet is being tested in D.C. and at Watt Road on I-40**
  - **Ft Bragg installation**
- **Weigh stations on Tennessee interstate highways are equipped with ORNL radiation detectors**
- **ORNL technologies were featured on ABC's "World News Tonight" in December**

ESTD is the Engineering Research Division of ORNL

- **~330 research engineers and support staff**
- **~$100 million per year budget**
- **Research in a broad array of areas**
  - **Buildings**
  - **Industrial Systems**
  - **Energy Efficiency Technologies**
  - **Cooling, Heating, and Power (trigen, cogen)**
  - **Electronics Fabrication**
  - **Sensors, Controls, Lasers, Optics**
  - **Robotics, Machine Vision**
  - **Transportation Research**

Technologies

ESTD Honors and Awards

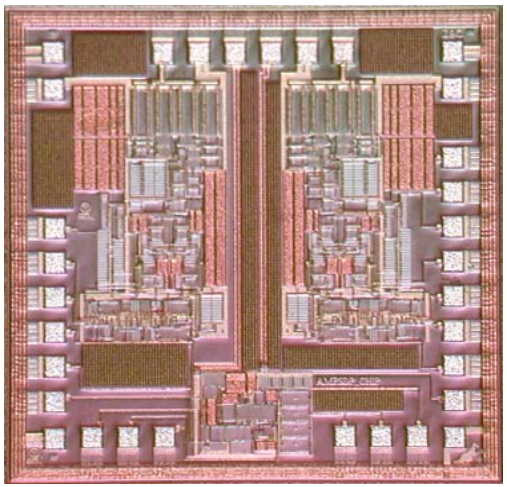
Raman Spectroscopy-Based Chemical Analyzer (RAMITs)

The Ramits Instrument developed by Tuan VoDinh (LSD), Alan Wintenberg (ESTD), Joel Mobley (LSD), Brian Cullum (LSD), Shane Frank (ESTD), David Stokes (LSD), and Bob Maples (RIS Corp.) is the winner of an R&D 100 Award for 2003.

Designed for use in the field by FBI agents, the Ramits Instrument can rapidly and automatically identify hazardous and other chemicals from their Raman spectra. No physical contact with the sample is needed – the instrument can "see" through colored glass bottles or even translucent plastic bags.

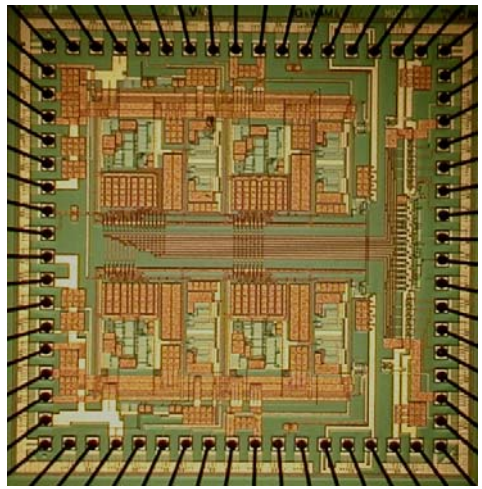
Silicon-on-Sapphire (SOS) Integrated Circuits for High Temperature Applications

Rail-to-Rail High Temperature OPAMP

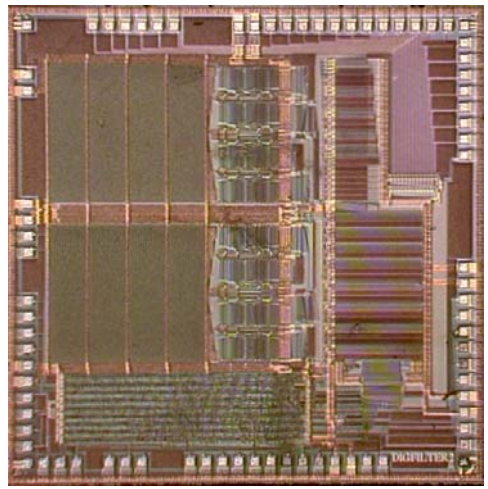


Constant Slew Rate Design

High-Resolution ΣΔ ADC Chipset (0.5μm SOS-CMOS)



4th-Order ΣΔ Modulator



Digital Decimation Filter

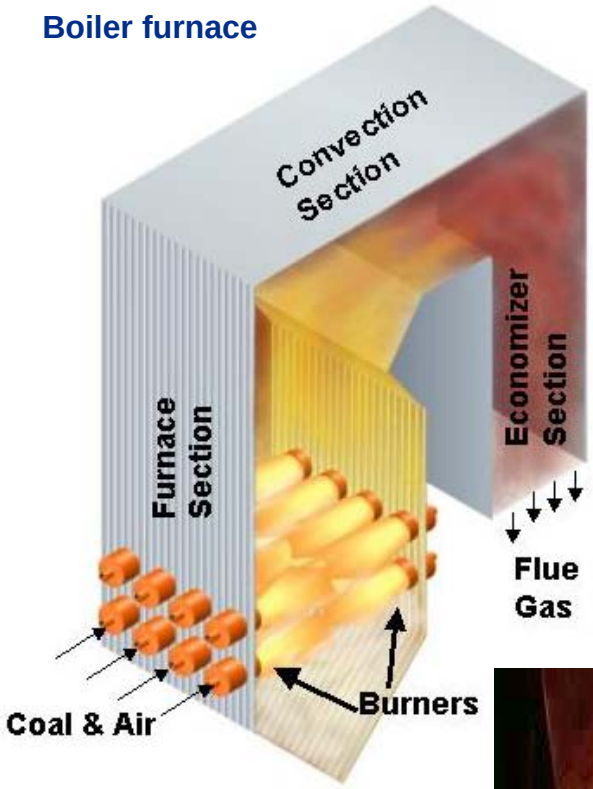
- ***Designed for single-supply 3.3V applications***
- ***225°C operation***
- ***Both designs are first of a kind***
- ***Both designs will give sponsor competitive advantage in their marketplace***

Flame Doctor®
Burner-monitoring System

Stuart Daw and Charles Finney (Sponsor: EPRI; Partner: B&W)

Flame Doctor

Boiler furnace



- Coal is 22% of U.S. energy; utilities produce 27% of NOx
- No reliable way to monitor individual burners in utility boilers
- Flame Doctor hardware/software assesses flame quality in each burner in real time so operators can make adjustments
- Builds on chaos work by division staff since early ’90s
- In testing at multiple utilities; commercial release soon
- Up to 10-20% reduction in NOx, increased fuel and plant efficiency

► Flame Doctor provides information, using existing equipment, otherwise unavailable to operators

Before: dark and dirty

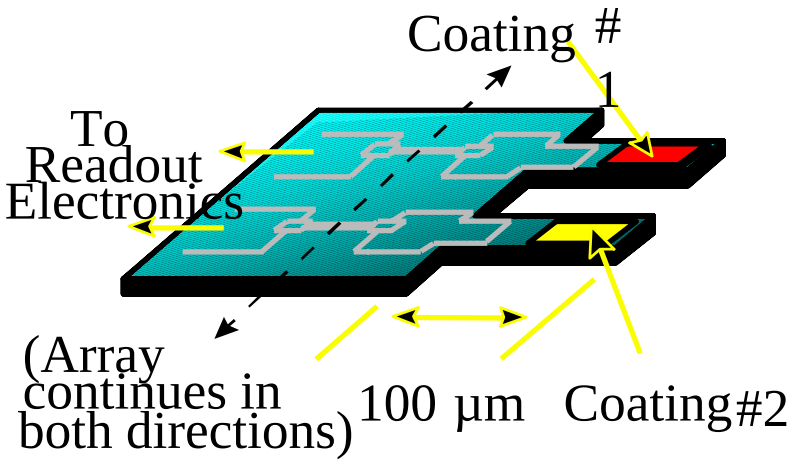
After: bright and clean

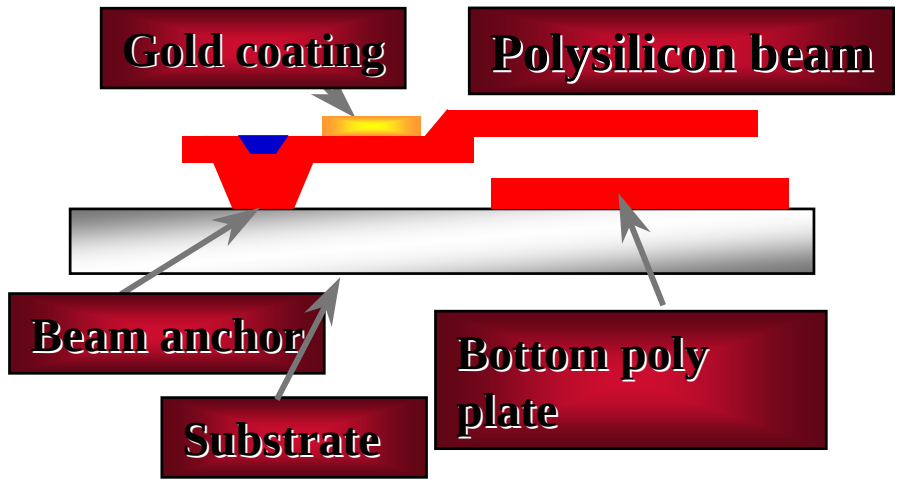
A New Diagnostic Instrument Has Been Developed and Demonstrated for USAF Aircraft Fuel Pumps (C-141)

Advanced Lasers, Optics, and Diagnostics Technology Group

Electrically Readable Microcantilever Arrays - Key to Low-cost, low-power sensing

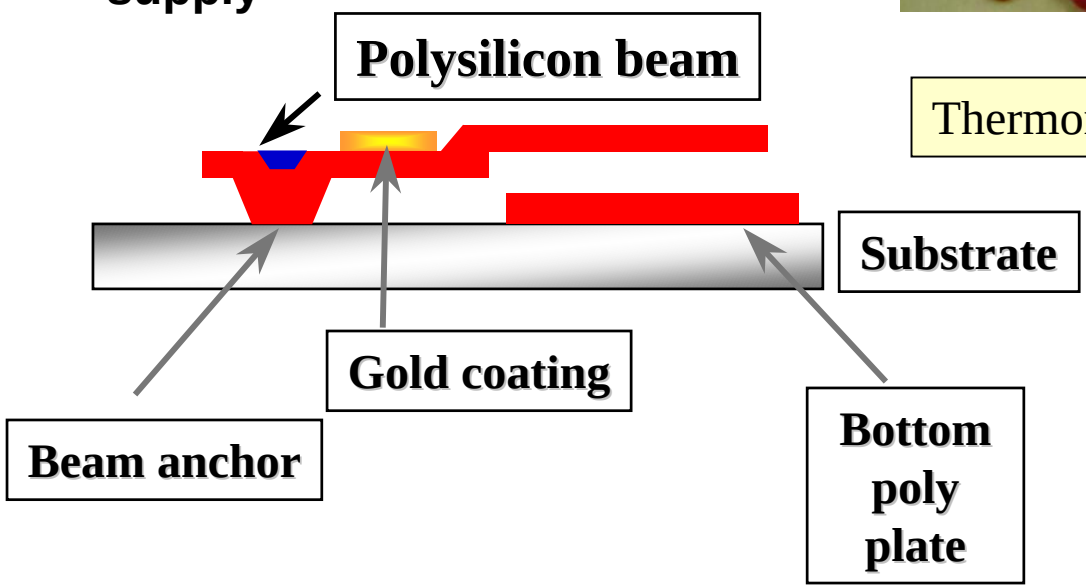
- **ORNL presently has several patents issued and pending and over a dozen disclosures on the technology**
- **Utilizing *arrays* of microcantilevers on a *single chip* with *customized coatings* to produce application-specific programmable sensors**
- **Test have been conducted on hydrogen, humidity, and mercury**
- **Initiating work on carbon dioxide and room occupancy**

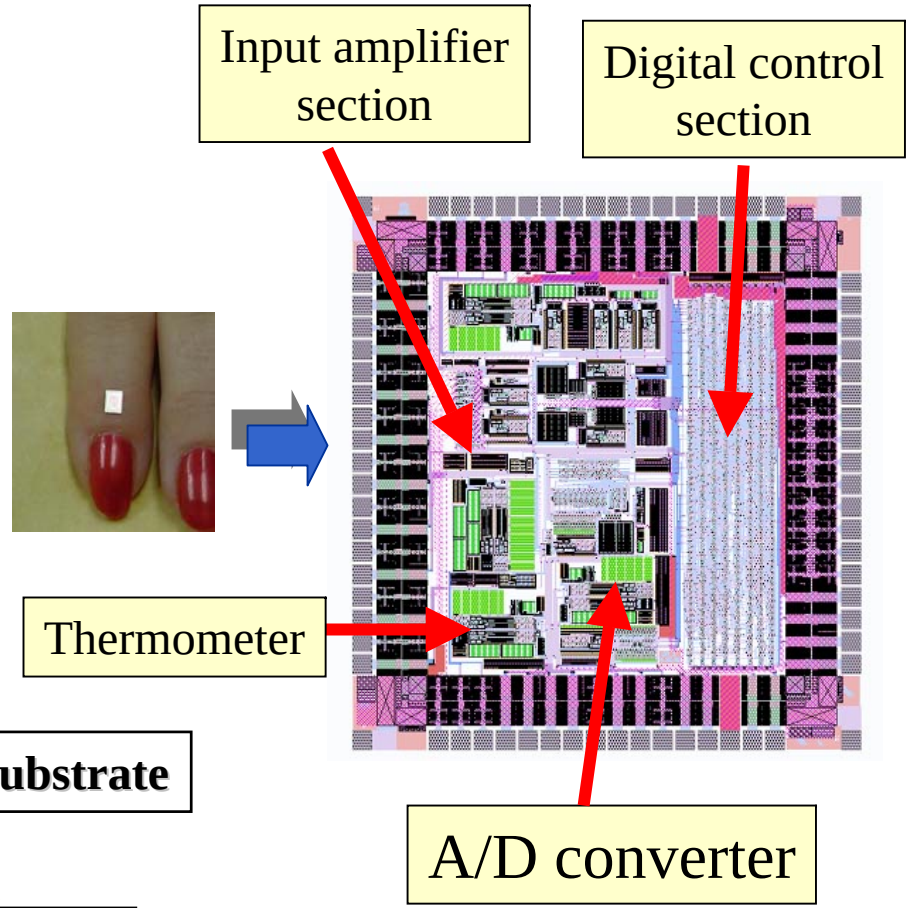




The GS2 – 3rd Generation Microcantilever Sensor Readout Chip

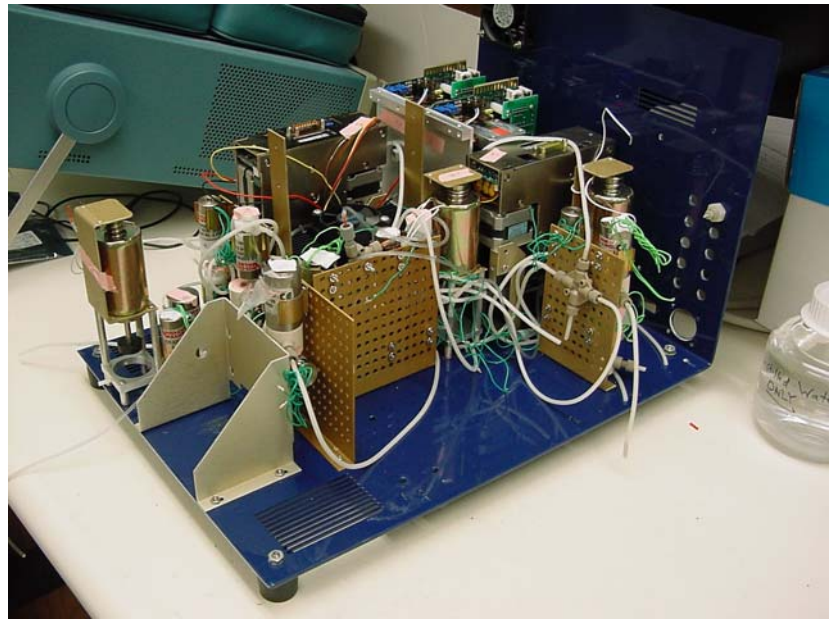
- **The GS2 can read out 10 cantilevers at once**
- **Includes on-chip thermometer**
- **It converts the analog signal with the 10-bit ADC on chip**
- **Interfaces through simple standard serial interface**
- **Low power dissipation ~ 1mW continuous on single 3.3V supply**

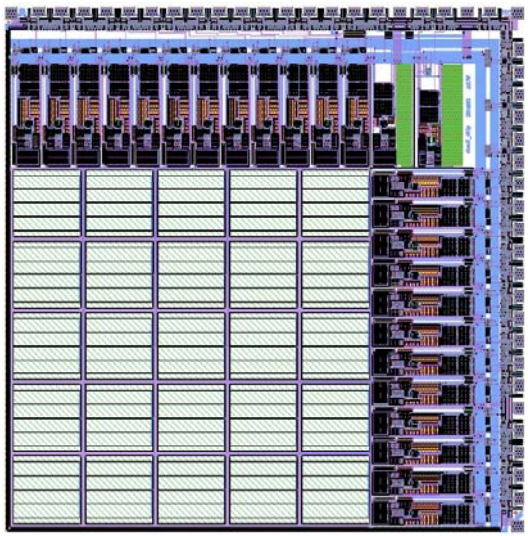




Advanced Multi-Functional Biochip

Collaboration with Advanced Biomedical and Science Technology group of LSD
4th year of 5 year DOE sponsored project
Winner of 1999 R&D 100 Award
Research team includes engineers, microbiologists, physicists, biochemists and programmers





Air-Sampling Biosensor Instrument Development

- Samples air for multiple, targeted biological agents
- Lyses cells to obtain DNA and amplifies DNA via PCR
- Biosensor unit contains
  - DNA and antibody probe array
  - Solid-state laser, optics and detection chip
- Custom Electronics for control and data acquisition
- RS485 interface to host PC and LabView-based software

DNA5 Chip - An ASIC for fluorescence detection

- 5x5 photodiode array with individual amplifiers
- pixel size – approximately 600 microns square, 640 microns center to center
- amplifiers configurable as transimpedance amps or as integrators
  - transimpedance amp has voltage programmable gain (MOSFET feedback)
  - integrator has 2pF integrating capacitor and CMOS reset switch
- multiplexed output to 50x amplifier
- built-in demodulator (follows 50x amplifier)
- implemented with 1.5 micron AMI process

ESTD Is Managing DOE Cross-Cut Wireless Telemetry Program

Reliable Ubiquitous Sensing to Improve Efficiency, Reduce Waste and Emissions, and Improve Raw Material Utilization

Objectives

Demonstrate reliable wireless telemetry for industrial sensor applications
Develop advanced wireless communications techniques to improve performance in harsh environments
Validate performance merits for energy savings, process efficiencies, and product quality

Successful Demonstrations

Timken Steel

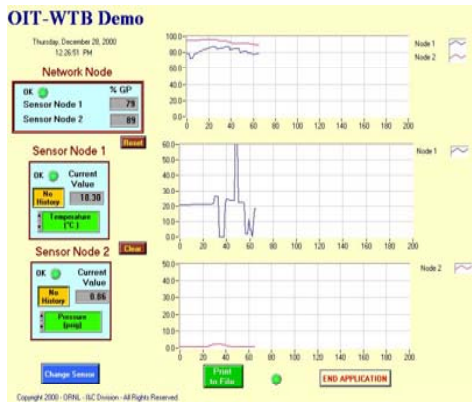
Outside transmitter

Line of Sight to LUT Cabin

Wireless Development

bi-directional transceiver

Bowater Paper



The prospect of being able to deploy new sensors rapidly anywhere in a manufacturing plant without the costs of cabling, connections, and associated labor presents a significant opportunity for using advanced wireless sensors in the future.

Manufacturing Process Controls for the Industries of the Future
National Research Council – 1998

Critical Issues

Robustness
Security
Battery life
Interference
Legacy interfaces

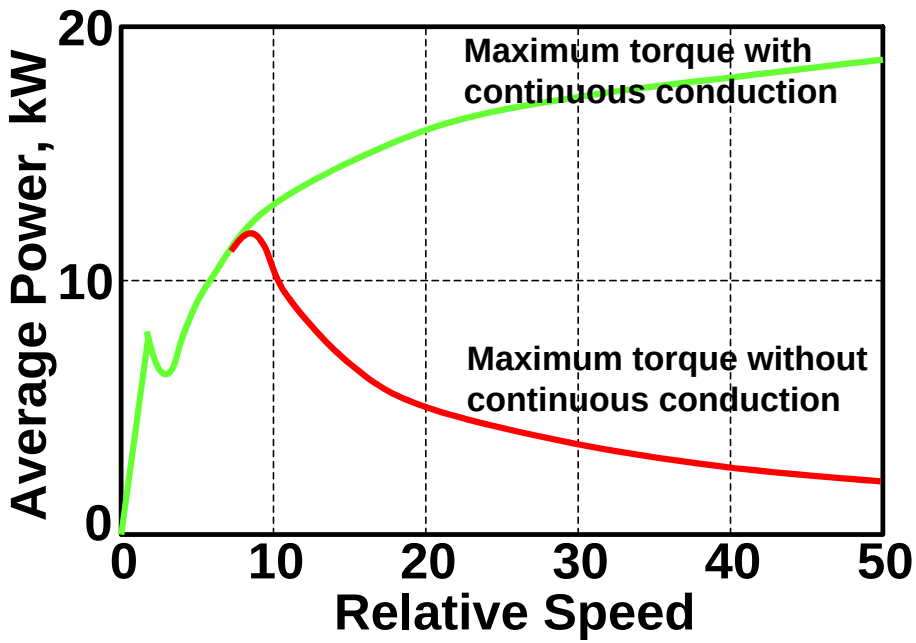
Robotics and Energetic Machines

DEMONSTRATION OF HUMAN-STRENGTH AMPLIFICATION CONTROLS FOR EXOSKELETONS (SPONSOR: DARPA-DSO)

- **Lower-limb exoskeleton test bed completed for sensing and controls development, test, and demonstration.**
- **Haptic (force, torque, motion) sensing interfaces at waist and feet for very high closed-loop (bandwidth) sensing and controls.**
- **“Transparent” strength-amplification force controls for load-carrying.**
- **Adjustable amplification ratios up to 100:1.**
- **Sensing and controls stability under high impact loads at the foot area.**

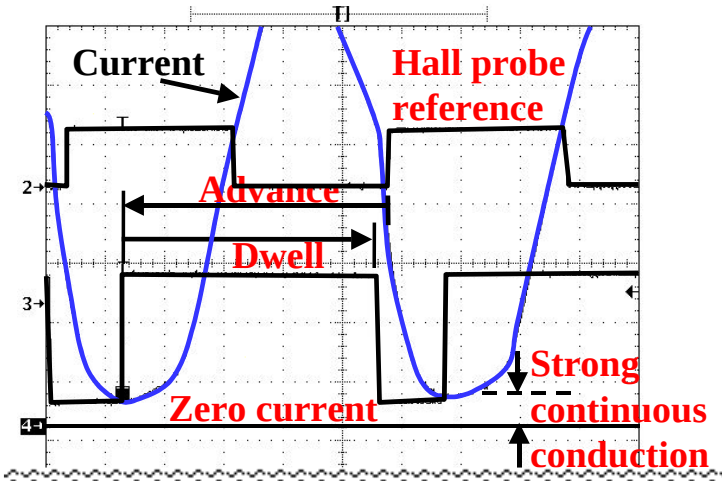
Controlling Electric Switched Reluctance Motors to Deliver Constant Power at High Speeds

Background: During collaboration with a heavy vehicle manufacturer ORNL identified a new capability for SRMs to deliver increased power using continuous current conduction*.



* Conventional operation zeroes current every cycle.

Status: On Feb. 5, 2003 a PEEMRC team demonstrated continuous current conduction in an SRM. It was abrupt and occurred in a narrow dwell band.



Challenge: Design and build an inverter that will drive an SRM to deliver high constant power at high speeds using continuous current conduction.

For Buildings, Energy-Saving Technologies include:

- **Hardware and software**
- **Laboratory assessments**
- **Advances in national standards, field assessment methods, diagnostics**
- **Technology and design review expertise**
- **Advanced field assessments**
- **Field demonstrations**

Two DOE National User Facilities offer Unique Building R&D Equipment and Capabilities

Buildings Technology Center (BTC)

Cooling, Heating and Power Integration Laboratory

ORNL R&D Building Technologies

- **Major Programs:**
  - Space Conditioning & Refrigeration
  - Thermal Insulation & Building Mat'ls
  - Appliances & Hybrid Lighting
  - ZEB and Building America
- **Recent Achievements:**
  - 1 kWh/day refrigerator
  - CFC replacements
  - Unequal, parallel compressors for commercial refrigeration
  - Frostless heat pump
  - Heat pump water heater
  - Charge indicator and COP meter
  - Wall thermal rating system
  - Moisture tool
  - 1st attempt at low cost ZEB

Rotatable guarded hot box in the Buildings Technology Center. The hot box is used to test the thermal performance of walls.

“Drop-in” heat pump water heater

- New designs
  - Same electrical and plumbing “footprint” as conventional
- Energy Factor
  - 1.5 to 2.5 compared to 0.95
  - Beta unit improved from 1.0 to 2.5 in BTC Lab
- 3 manufacturers currently
- DOE-sponsored field tests with utility partners across 10 states
  - 50% energy savings
  - Two-year payback potential
- FY03 plans:
  - Complete durability/reliability tests on 10 HPWHs including the most recent drop-in and add-on models

Field Test Expertise Important

- **Completed national field evaluation of “drop-in” HPWH (2001 R&D 100 winner) – demonstrated 50% reduction in energy consumption as compared to resistance water heater**
- **HPWH durability testing**
  - **Accelerated life tests completed for “drop-in” HPWH**
  - **Round II accelerated life testing program begun for other units**
  - **ORNL unique facility in 3144 with units installed shown in photo**

Commercial Refrigeration

Partners: Foster Miller, SCE, Hill PHOENIX

- Motivation:
  - **Stricter food safety codes require lower display case temperatures (i.e., more energy)**
  - **Current system designs result in high refrigerant charges and large line losses**
- Significant DOE Successes to Date:
  - **Unequal, parallel compressor systems (16% energy savings) are now over 90% of market**
  - **Distributed compressor systems show promise**
  - **Warm Liquid Defrost Concept Proven for Display Cases**
- FY03 Plans:
  - **Fabricate energy-efficient case design (goal = 20% reduction in energy use)**
  - **Develop case rating procedure**

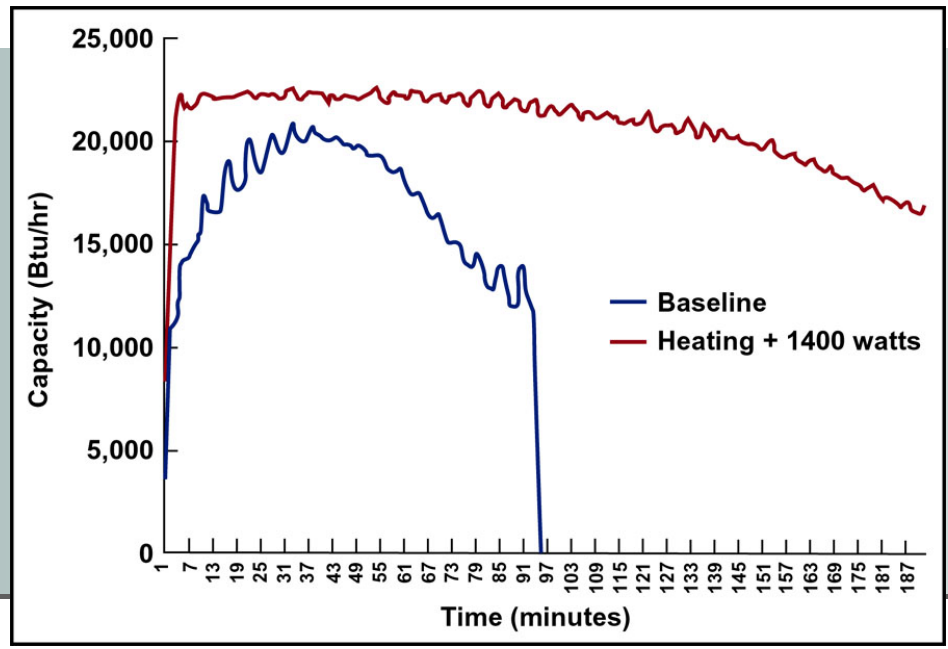
Frostless heat pump

Key innovation

Addition of heat to the accumulator to warm the refrigerant in the outdoor coil

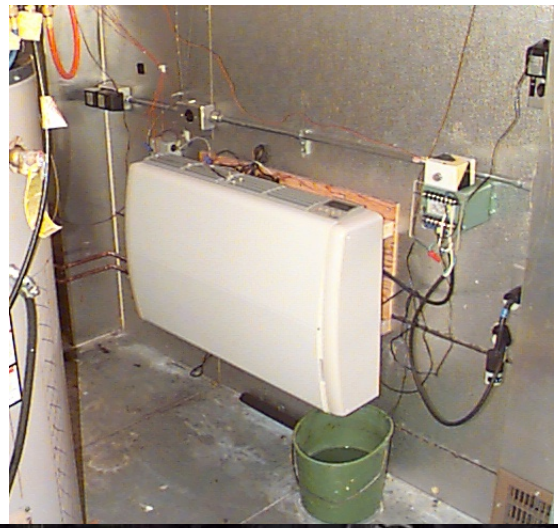
- **Eliminates cold air blowing indoors**
- **Retards frost formation**
- **Increases heating capacity**

Two units in TVA employee homes being monitored

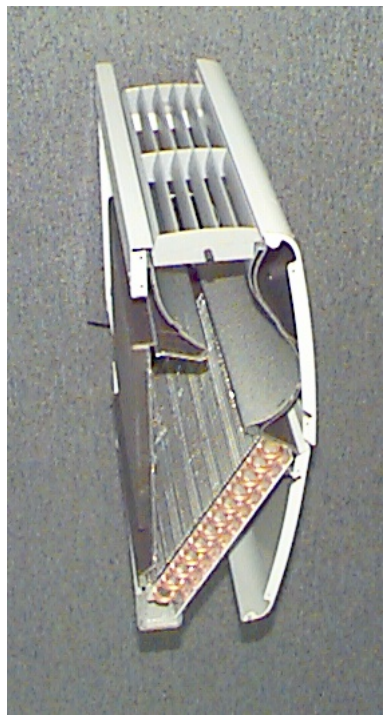


Heating capacity comparison at 35° F / 75% RH–12 SEER unit

Limited R&D on Distributed HAC (keep the V separate)



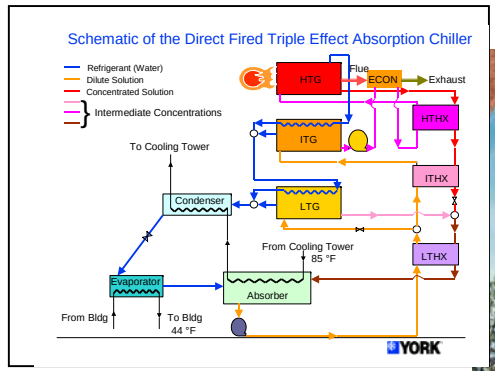
- **Distributed HAC may be most critical to energy-saving strategies for buildings and production lines**
- **Allows on-off (simple) control**
- **Ventilation a security issue**

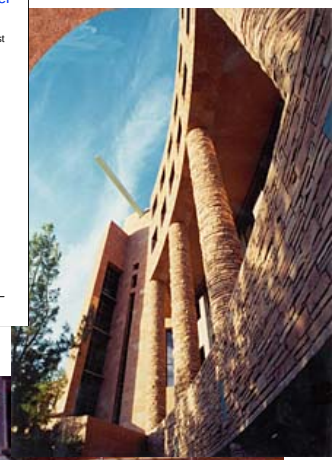


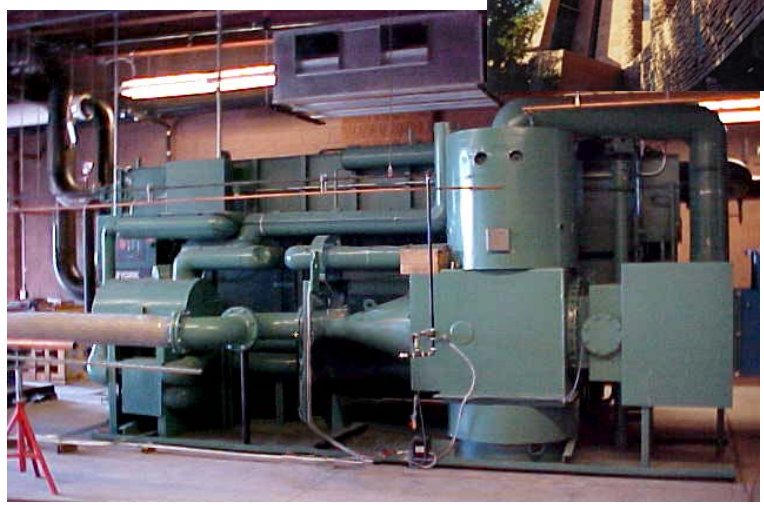
Triple-Effect Chiller Begins Its Vegas Run

Cooling, Heating and Power Group

- **First real-world trial of a *triple-effect* LiBr-Water absorption chiller:**
  - **Direct Fired Version of the DCC Cycle [ORNL patent]**
  - **ASME Pressure Vessel Code Compliant**
  - **Novel Generator and Burner System**
  - **NO_X and CO emissions below 15 ppm**
  - **Economizer used to recover heat from exhaust**
  - **ADVAGuard™ 750 corrosion inhibitor**
  - **York's micropanel for control and building integration**
  - **COP (IPLV): 1.37**
- **Provides 400 tons of cooling to Clark County Government Center's campus including a 385,000 sq. ft. building.**







Next generation envelope materials to save energy and control moisture

- **BTC User Facility Material Hygrothermal Properties Lab**
- **Procedures and database for material properties underway (35 subscribers)**
- **Worked with City of Seattle and material manufacturers to address $500M building damage due to wind driven rain**
- **Moisture control design tool now available from BTC (1,500 subscribers)**
- **FY03 Plans:**
  - **Vapor control recommendations for residential buildings, by region**
  - **Optimum design for crawlspaces in hot/humid climates**

Roofing studies

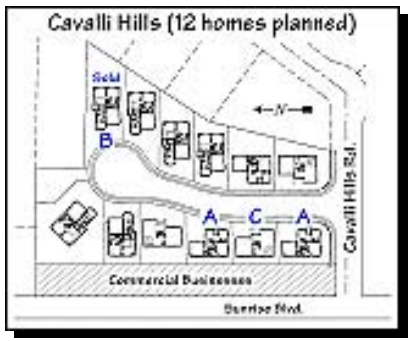
- **Development and testing of reflective coatings:**
  - **24 coatings tested, representing 75% of market**
  - **35 sponsors, $1M (80% private $)**
  - **CEC now funding work on cool colored coatings with LBNL**
- **Shading benefits of photovoltaics being estimated**

•FY02: Roof energy savings calculator
•FY03: Extend calculator:
  –For residential roofs
  –To estimate peak reductions

Researchers at ORNL's Envelope Systems Research Apparatus

IR REFLECTIVE COLORS FIELD TESTS Collaborative R&D Between Industry, ORNL, LBNL, and SMUD Sponsor: The California Energy Commission

- **Demonstrations in Sacramento, CA**



- **Field Testing at ORNL on ESRA**

Benefits of IR Reflective Colors

Reflect more sunlight and stay cooler
Lower utility bill for cooling the house
Architectural appeal
Better fade resistance

- **Field Exposure Sites**

Industrial Facilities Program

- **Partnership between DOE Programs**

- **Serving federal industrial customers with expertise from ORNL, Industrial Assessment Centers (IAC) and Best Practices Specialists**

- **Services offered: Assessments, training, assessment follow-up including implementation options and other opportunities for assistance**

Radford Army Ammunitions Plant — Multi-day Best Practices Specialist Assessments

- **Identified opportunities**
  - **Steam: Boiler combustion control, boiler stack losses, condensate recovery**
  - **Compressed air: Reduce plant pressure, repair leaks, install storage tank, eliminate point-of-use desiccant dryers**
- **Recommended savings**
  - **233,992 MMBtu/yr source**
  - **$377,500/yr**
- **Currently implemented savings (boiler controls)**
  - **204,108 MMBtu/yr source**
  - **$290,000/yr**

Denver Mint (Treasury) — Plant-Wide IAC Assessment, On-Site Presentation of Results

- **Opportunities identified**
  - **Steam condensate recovery, process heating operations, lighting, compressed air, process insulation**
- **Recommended savings**
  - **14,435 MMBtu/yr source**
  - **$73,620/yr (includes water savings)**
- **Currently implemented savings**
  - **4,368 MMBtu/yr source**
  - **$36,000/yr (condensate use, furnace operations, lighting, compressed air leaks)**

NASA Kennedy Space Center — ORNL IFP/ALERT Team Assessment

- **Multi-day assessment of payload support buildings**
- **Recommended savings**
  - **33,512 MMBtu/yr source**
  - **$178,000/yr (AHU, cooling, heating, lighting, VSDs)**
- **Currently implemented savings**
  - **11,300 MMBtu/yr source**
  - **$68,000/yr (cooling and heating)**

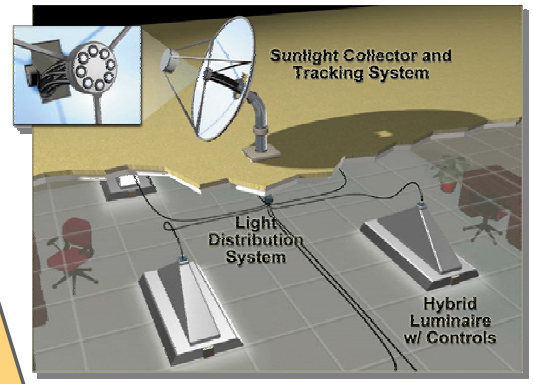
Hybrid Lighting

Hybrid Lighting Uses

- Full solar energy spectrum
- Natural and electric light sources
- Networks of optical fibers
- Hybrid luminaires and control systems

•Projected Benefits

- **Payback ~ 2–5 years after R&D**
- **Student/worker productivity shown to be much higher under natural lighting**
- **Significant public interest**



Hybrid Lighting Design Concept

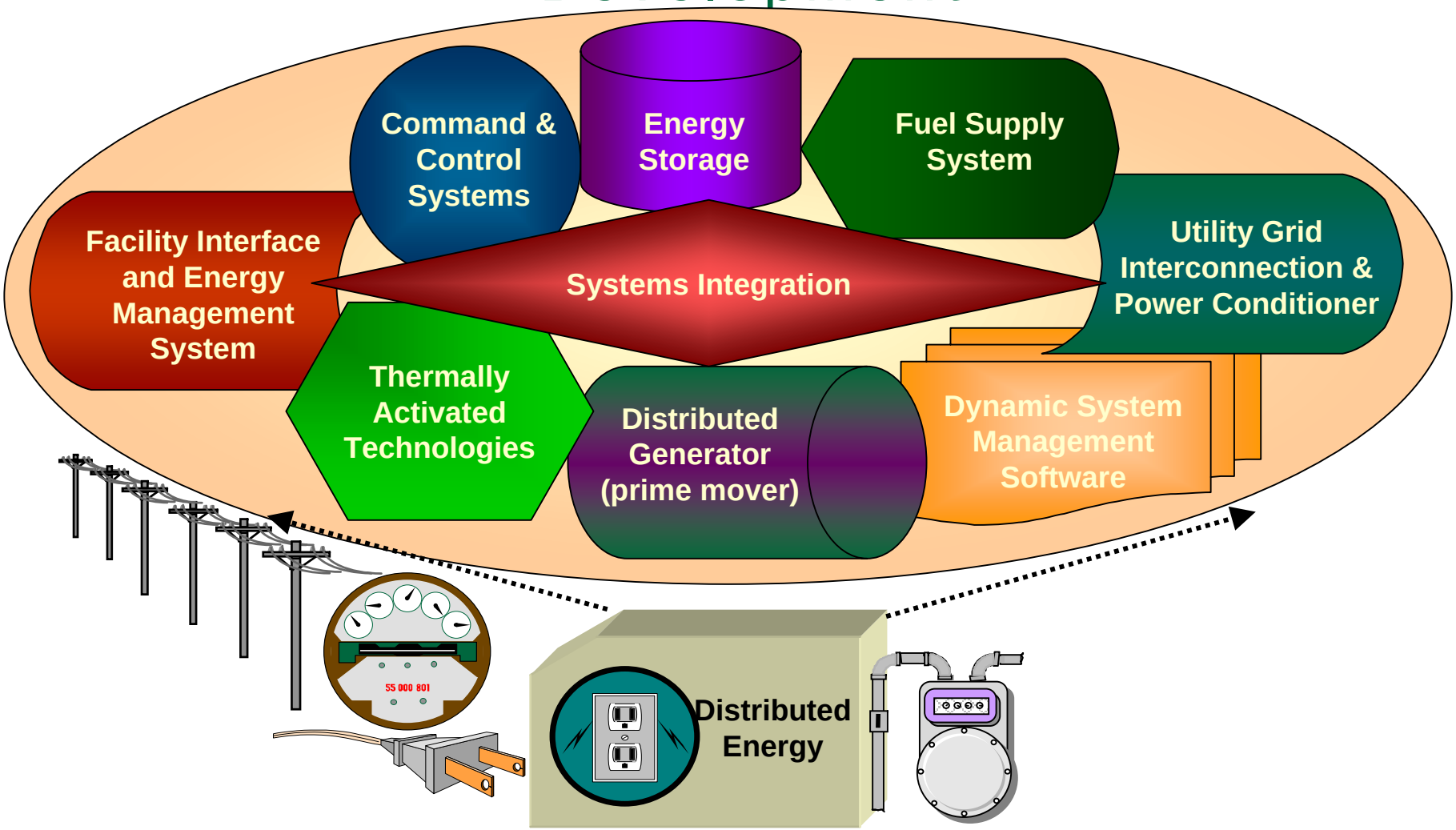
Prototype Hybrid Luminaire

A hybrid lighting system is now operating at local building

- **Sunlight distribution efficiency – 50%**
- **Color temperature and chromaticity values of distributed sunlight match sunlight very closely**
- **Six months of fault-free operation at Ohio University installation**
- **Alpha demos scheduled in MS, AL, NV, and CA in next 12 months**
- **Three parties negotiating for license**

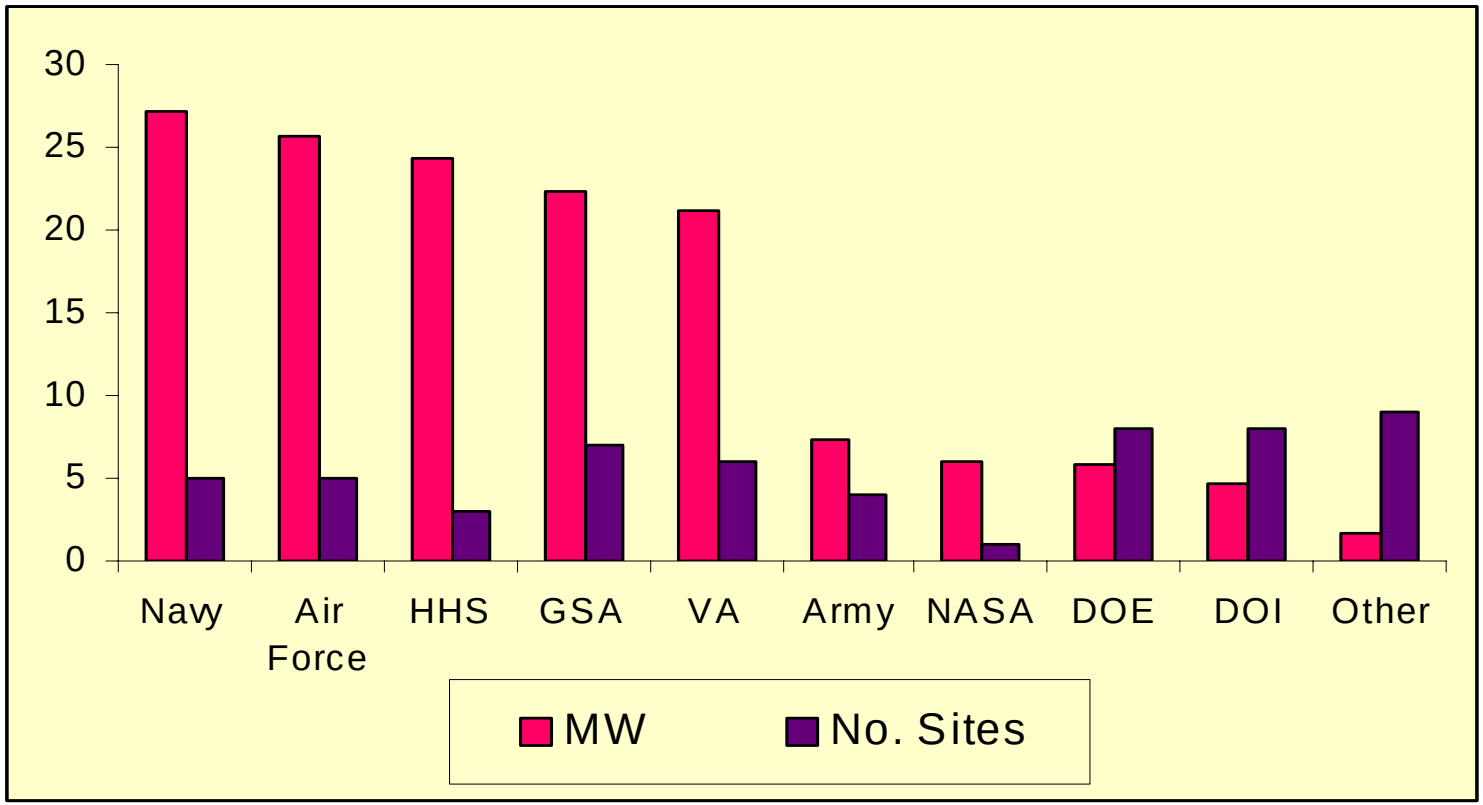
ORNL HSL lab being lit by distributed sunlight.

DER Strategy
Distributed Energy System Development



ADD CHP

Accelerated Development and Deployment of Cooling, Heat and Power Systems, Who's In



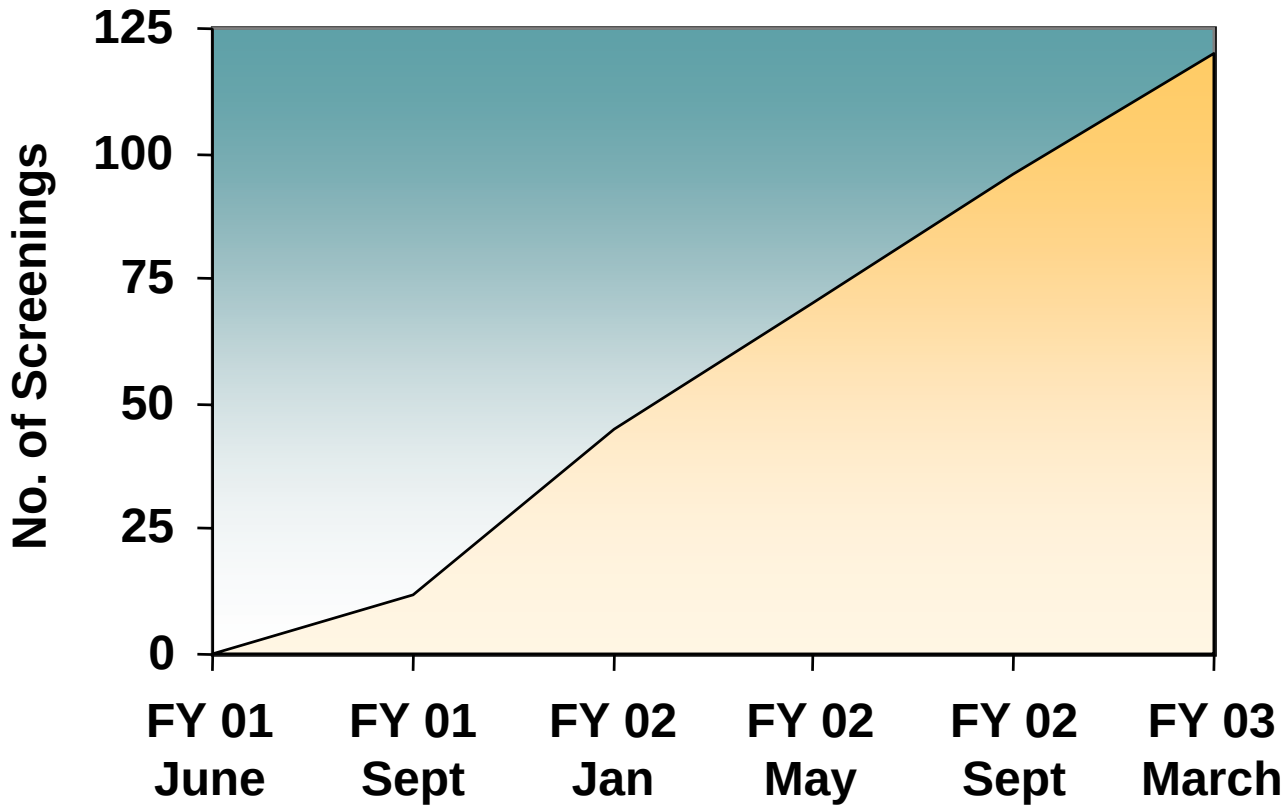
Twenty Nine Palms Air Ground Combat Center, USMC

- **7-MW, dual-fuel cogen system; inaugurated 2/2003 — energy security a primary driver**
- **Annual cost savings: $5.8M**
- **Savings subsidized 1 MW of PV**
- **75% efficiency (design target) — twice U.S. grid average**

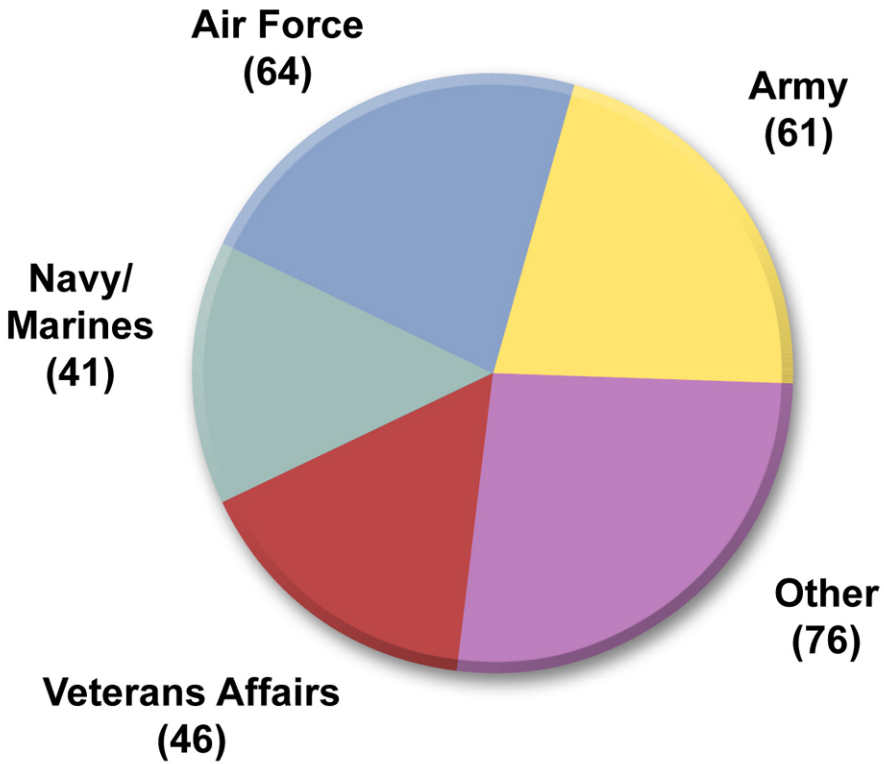
- **Exhaust for district hot water and 200-ton chiller**
- **ORNL support catalyzed efforts, contributed to more efficient design**

Federal Facilities Show Interest in CHP

Sites have requested >120 CHP screening reports



Screening Results Mirror Market Sector Interest



MW of CHP potential by agency, from results of screened projects with <11 years simple payback

(Total = 69; ORNL 2003)

ORNL, ESTD, and the Buildings Technology Center

- **Wide range of expertise in process-related, security-related, and energy-related technology R&D, performance assessments and field application, and verification of field performance**
- **Extensive expertise and involvement in related national standards development, application methods development, diagnostics, and performance measurement**

Contact Info

- **http://www.ornl.gov/btc**
- **http://www.ornl.gov/sci/eere/**
- **http://www.ornl.gov/sci/engineering_science_technology/**

- **Mike MacDonald**
  - **macdonaldjm@ornl.gov**
  - **865-574-5187**